CLAIMS

What is claimed is:

1. A projection optical system of an exposure device, comprising:

an optical element having a rotationally symmetrical aspheric surface,

wherein a surface shape of the optical element is represented by a non-even function Z = g(h), a distance between the aspheric surface and a plane at a vertex of the surface perpendicular to the rotation axis of the aspheric surface being represented by Z where the distance is measured parallel to the rotation axis, and a distance from the rotation axis is h, and

wherein the optical element performs a projection exposure on a second surface of an image of a pattern formed on a first surface.

2. The projection optical system of the exposure device of claim 1, wherein the projection optical system comprises six optical elements that are mirrors.

3. The projection optical system of the exposure device of claim 1, wherein non-even function Z = g(h) has a derivative that is zero on the rotation axis.

4. The projection optical system of the exposure device according to claim 1, wherein the projection optical system of the exposure device is a reflection type projection optical system comprising a reflection system.

5. The projection optical system of the exposure device according to claim 1, wherein the function Z=g(h) is a function having power series terms.

6. The projection optical system of the exposure device according to claim 1, wherein the function Z=g(h) is a function having odd function terms added to even function terms.

7. The projection optical system of the exposure device according to claim 5, wherein a degree of each term of the power series is a number greater than 1.

8. An exposure device to illuminate a mask with exposure light, the mask being disposed in a first surface, to project an image of a pattern formed in the mask via a projection

optical system onto a photosensitive substrate disposed in a second surface, comprising:

a plurality of reflecting mirrors, arranged to reflect source light and illuminate the mask;

a first variable aperture control unit;

a first variable aperture diaphragm, coupled to and controlled by the first variable aperture control unit, arranged in a path of the source light to control a shape of the source light; and

a projection optical system comprising

an optical element having a rotationally symmetrical aspheric surface,

wherein a surface shape of the symmetrical aspheric surface of the optical element is represented by a non-even function Z= g(h), a distance between the aspheric surface and a plane at a vertex of the surface perpendicular to the rotation axis of the aspheric surface being represented by Z wherein the distance is measured parallel to the rotation axis, and a distance from the rotation axis is h, and

wherein the optical element performs a projection exposure on the second surface of an image of a pattern formed on the first surface.

9. The exposure device of claim 8, wherein the projection optical system comprises six optical elements that are mirrors.

10. The exposure device of claim 8, wherein the non-even function Z = g(h) has a derivative that is zero on the rotation axis.

11. The exposure device of claim 8, further comprising:

a second variable aperture control unit; and

a second variable aperture diaphragm, coupled to and controlled by the second variable aperture control unit, arranged in the projection optical system to control a shape of reflected light.

12. An exposure method comprising:

illuminating a mask with exposure light; and

forming, on a photosensitive substrate, an image of a pattern formed in the mask based on the exposure light having illuminated the mask using a projection optical system comprising an optical element having a rotationally symmetric aspheric surface represented by a non-even function Z = g(h), a distance between the aspheric surface and a plane perpendicular to the

rotation axis of the aspheric surface being represented by Z wherein the distance is measured parallel to the rotation axis, and a distance from the rotation axis is h, and wherein the optical element performs a projection exposure on a second surface of an image of a pattern formed on a first surface.

13. The exposure method of claim 12, wherein the non-even function Z = g(h) has a derivative that is zero on the rotation axis.

14. A projection optical system, comprising:

an optical element having an aspheric surface with a configuration represented by a non-even function Z = g(h), a distance between the aspheric surface and a plane perpendicular to the rotation axis of the aspheric surface being represented by Z wherein the distance is measured parallel to the rotation axis, and a distance from the rotation axis is h, and

wherein the optical element performs a projection exposure on a second surface of an image of a pattern formed on a first surface.

15. The projection optical system of claim 14, wherein the projection optical system comprises six optical elements that are mirrors.

16. The projection optical system of claim 14, wherein the non-even function Z = g(h) has a derivative that is zero on the rotation axis.

17. The projection optical system of claim 14, wherein the non-even function of the configuration of the aspheric surface of the optical element is represented by the following equation:

$$Z = \frac{h^2 / r}{1 + sqrt\{1 - (1+k)h^2 / r^2\}} + \sum_{n=2}^{28} Cnh^n ,$$

wherein the distance measured parallel to the rotation axis, Z, is an optical axis direction sag amount from a plane, r is a radius of curvature at a surface vertex, h is a distance from the rotation axis, k is a predetermined cone coefficient wherein when k = 0, a first term is an expression for a spherical surface and when k = -1, the first term is an expression of a paraboloid, and C2 – C28 are predetermined 2nd through 28th aspheric coefficients.

18. The projection optical system of claim 14, wherein Z is a function having power series terms wherein odd number degree terms are added to even number degree terms and a degree of each term of the power series terms is greater than 1.

19. The projection optical system of claim 14, wherein the system is a reflection system.

20. The projection optical system of claim 14, wherein the projection optical system is a non-telecentric optical system.

21. The projection optical system of claim 14, further including:

a variable aperture control unit; and

a variable aperture diaphragm controlled by the variable aperture control unit, arranged to control a shape of reflected light.

22. A projection optical system, comprising:

an optical element having an aspheric surface with an aspheric surface configuration represented by a function having maximized degrees of freedom for the aspheric surface configuration of a whole surface of the at least one optical element,

wherein the optical element performs a projection exposure on a second surface of an image of a pattern formed on a first surface.

23. The projection optical system of claim 22, wherein the function of the aspheric surface configuration of the optical element is represented by the following equation:

$$Z = \frac{h^2 / r}{1 + sqrt\{1 - (1+k)h^2 / r^2\}} + \sum_{n=2}^{28} Cnh^n ,$$

wherein a distance between the aspheric surface and a plane perpendicular to the rotation axis of the aspheric surface is represented by Z where the distance is measured parallel to the rotation axis, r is a radius of curvature at a surface vertex, h is a distance from the rotation axis, k is a predetermined cone coefficient wherein when k = 0, a first term is an expression for a spherical surface and when k = -1, the first term is an expression of a paraboloid, and C2 – C28 are predetermined 2nd through 28th aspheric coefficients.

24. The projection optical system of claim 22, wherein the system is a reflection system.

25. The exposure method of claim 12, wherein the image of the pattern is formed by stepwise scanning and illuminating the mask in a predetermined direction to obtain a plurality of shot regions that provide a whole pattern of the mask.

26. The exposure device of claim 8, further including:

a second variable aperture control unit; and

a second variable aperture diaphragm, coupled to the second variable aperture control unit and the projection optical system, and arranged to control a shape of light entering the projection optical system.

27. A method to manufacture microdevices using a projection optical system having at least one optical element having a rotationally symmetric aspheric surface and liquid crystal display cells, comprising:

illuminating a mask with exposure light;

forming, on a photosensitive substrate, an image of a pattern formed in the mask based on the exposure light having illuminated the mask using a projection optical system comprising an optical element having a rotationally symmetric aspheric surface represented by a non-even function $Z = g(h)$ having a derivative that is zero on a rotation axis, wherein a distance measured parallel to a rotation axis is represented by Z and a distance from the rotation axis is h, and wherein the optical element performs a projection exposure on a second surface of an image of a pattern formed on a first surface;

forming color filters in accordance with the image; and

assembling liquid crystal display cells using the photosensitive substrate and the color filters.

28. A projection optical system, comprising:

optical means for reflecting light to form an image of an object in a wafer, the optical means having an aspheric surface with a configuration represented by a non-even function $Z = g(h)$, a distance between the aspheric surface and a plane perpendicular to the rotation axis of

the aspheric surface being represented by Z where the distance is measured parallel to the rotation axis, and a distance from the rotation axis is h.